Concept Paper for Variable Length Frames

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Objective

Investigate methods to combine the various CCSDS variable-length frame protocols with the various CCSDS synchronization and channel coding protocols, select at least one for standardization, and update the suite of standards accordingly. This likely involves writing a new, thin, Blue Book.

Key Problems

Technical: Select one (or both) protocols:

- ASMs and frame length fields in existing protocols
- Generic Frame Procedure (GFP)

Implementation: Publication method

- Modifications to existing Blue Books
- New “shim layer” Blue Book

Existing coding standards (1 of 2)

TM coding (131.0-B)

- Convolutional or uncoded: Fixed-length frames of any size get 32-bit ASMs to form SMTFs. They are convolutionally encoded, or uncoded.
- RS, Turbo, LDPC: Codeword-sized fixed-length frames are encoded.
- RS+CC: Codeword-sized fixed-length frames are encoded. Then ASMs are added, and the resulting CADUs are convolutionally encoded.
- Option for LDPC (1024,1/2) only: fixed-length frames of any size get 32-bit ASMs to form SMTFs. They are sliced and encoded.

SCCC (131.2-B)

- Fixed-length frames of any size get 32-bit ASMs to form ~~CADUs~~ SMTFs. They are sliced and encoded.

DVB-S2 (131.3-B)

- Fixed-length frames of any size get 32-bit ASMs to form ~~CADUs~~ SMTFs. They are sliced and encoded.

Existing coding standards (2 of 2)

Proximity-1 (211.2-B)

- Variable-length Transfer Frames get 24-bit ASMs and 32-bit CRCs to form PLTUs. These may be convolutionally encoded, or "sliced" and LDPC encoded.

TC (231.0-B)

- With TC SLP: Variable-length Transfer Frames may be concatenated. The result is encoded, start and tail sequences are added, and transmitted.
- With USLP: One variable-length Transfer Frame is encoded, start and tail sequences are added, and transmitted.

Option 1: Extend the use of ASMs

To support fixed-length frames, of any length, only one standard needs updating

- **TM Coding (131.0-b): Allow the use of ASMs and slicing with all block codes**
- **All other cases are already supported.**
- **In each case, the frame length could be a managed parameter.**

Three Space Link Protocols generate variable-length frames: TC, Prox-1, and USLP. All three include a frame-length field, or at least a mechanism to determine the frame length (USLP truncated header option).

To support variable-length frames

- **Allow the use of ASMs and slicing with all coding protocols. The decoder determines the frame length by parsing the Space Link Protocol header. This way, it can find the next ASM, and generally detect spurious ASMs.**

Benefits and Drawbacks of ASMs

Benefits

- ASMs are already partially supported by each of the CCSDS coding standards.

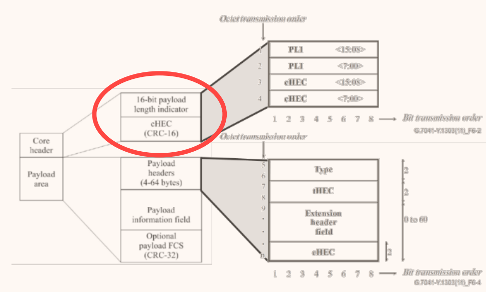
Drawbacks

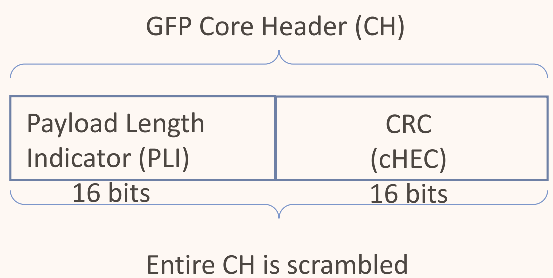
- The partial support is inconsistent, with different length ASMs and other variations.
- This requires a "layer violation" in which the coding sub-layer must parse the headers of the space link protocol in order to deliver delimited transfer frames. In some cases, this requires a managed parameter to know which Space Link Protocol is being used.

Option 2: Generic Frame Procedure (GFP)

GFP Core Header (CH) and its Role

- The GFP Core Header (CH) is a 32 bit field.
- It is composed of:
  - A 16 bit Payload length indicator (PLI)
  - A 16 bit CRC, the core header error control (cHEC)
  - The CH is scrambled by XORing with B6AB31E0.





- The Function of the CH is to provide:
  - The length of the frame
  - A sync marker for the frame (so start of a frame data block can be found)
  - 4 octet Fill Units for matching frame production to output data rate as necessary
  - Note that the cHEC may be used to guard against random bit errors (not a feature useful for a decoded bit stream)

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Benefits and Drawbacks of GFP

Benefits

- This could provide a uniform solution across all the RF standards, and also with the Optical standards.
- GFP provides a mechanism to generate idle symbols late in the data processing chain.

Drawbacks

- Frame lengths are duplicated in the GFP core headers and the Transfer Frame headers.
- Using GFP instead of ASMs requires removing ASMs from the existing standards.
- This is entirely new to the RF community. Adoption may be challenging.
- Markers are not readily found by eye. This makes testing and debugging slower and more difficult.

A question

- Is GFP part of the C&S sub-layer or the SLP sub-layer?

Straw poll

Which approach to Variable Length Frames do you prefer?

☐ An extended ASM approach, that has some heritage in the RF community

☐ The GFP approach, that has been selected by the Optical WG, and has some technical elegance

☐ Allow them both, at the risk that standardizing everything is akin to standardizing nothing

☐ Don't standardize VLF at all; it's silly

☐ Some new, different, and better idea

Choice of Implementation

1. Develop a new “shim” Blue Book
   Advantage: This approach would automatically cover all coding and protocol combinations, and assure consistency

OR

2. Modify the existing Blue Books to allow Variable Length Frames, with ASMs or GFP or both
   Advantage: Not all books would have to be edited simultaneously.

With either approach, every Blue Book will need editing.

The attached concept paper is written based on the first choice.
It proposes a Blue Book with the draft working title, “Transfer Frame Segmentation Protocol”.

Straw poll

How should we proceed towards standardizing Variable Length Frames (VLF)?

- ☐ **Develop a new “shim” VLF Blue Book for any combination of RF protocol, RF coding, and Optical standards**

- ☐ **Modify each of the existing coding Blue Books individually**

- ☐ **Some new, different, and better idea**

Concept Paper — Variable Length Frames

1. Purpose

The proposed work is to investigate methods to adapt the CCSDS synchronization and channel coding profiles so that they can use variable-length Transfer Frames from the CCSDS Space Link Protocols that generate them. The objective is to select at least one method for making these protocols work together, and to update the suite of standards accordingly. A likely outcome will be the development of a new Blue Book that will describe methods to partition variable length frames into Synchronization Marked Transfer Frames (SMTFs) suitable for error-correction encoding. This concept paper is written based on that assumption, but it is recognized that upon further study, the Working Group may decide that it is preferable to modify existing Blue Books instead.

2. Benefits

A segmentation protocol for variable length transfer frames would allow combining the existing CCSDS standards for protocols and coding in some new and potentially useful ways. The optical community is particularly interested in sending variable-length Ethernet packets using fixed-length optical codewords, and the existing radio-frequency standards should be prepared for similar needs. Another likely application is to send variable-length TC Transfer frames using codes from the "TM Coding" (131.0-B) standard on a ground-to-space link. USLP has a variable-length frame option, primarily intended for telecommand and proximity links that already support variable length frames, and it could make sense to support those with the "TM Coding" standard as well. One application would be in relay links: in a lunar environment for example, one might wish to send variable-length frames on a proximity link from a rover to orbiter, and then relay them to Earth without repackaging them (as is done now on relay links). Such combinations seem sufficiently natural that CCSDS should be forward-looking and explore the capability.

3. Requirements of prospective missions

An existing unfulfilled need is apparent from relay links from Mars to Earth via an orbiter. The first hop in such a link uses the Proximity-1 protocol with variable-length frames. For lack of a means to send variable-length frames on a Mars-to-Earth link, current orbiters repackage these into fixed-length AOS Transfer Frames for transmission to Earth using the "TM Coding" standards in 131.0-B.

There is considerable immediate interest in the commercial free-space optical communications community for transferring variable-length Ethernet packets. The favored solution is to use the Generic Framing Procedure (GFP) for compliance with existing hardware.

In the space research community, perhaps the most immediate application will be for relay links in the lunar environment. One application would be to transmit variable-length telecommand Command Link Transmission Units (CLTUs) over a relay link. The first hop in such a link may benefit from the use of a low-rate turbo code from the "TM Coding" Blue Book (131.0-B), or from a high-rate DVB LDPC or SCCC code from either the 131.2-B or 131.3-B Blue Books.

ANNEX 1 – Consistency with Charter

The charter of the Space Link Coding and Synchronization Working Group lists as the scope of activity, "Correct interaction with the procedures at the Data Link Protocol … layer shall be ensured." This concept paper proposes to improve such interactions, so it is in line with the charter.

A new CWE Project is defined in Annex 2.

ANNEX 2 – Proposed CWE Project

Title: Transfer Frame Segmentation Protocol (draft working title)

Document Number: (new)

Document Type: Blue Book

Description of Document: This new Blue Book will describe one or more methods to segment a stream of Transfer Frames, either of fixed length or variable length, into Sync Marked Transfer Frames suitable for error-correction encoding.

Applicable Patents: None anticipated

Book Editor (estimated resources + Agency Volunteering): Total resources: 6 work-months, led by NASA. It is anticipated that ESA and CNES will also have significant roles. Lead editor: NASA.

Expected Contributing Agencies: NASA, ESA, CNES

Expected Monitoring Agencies: DLR, CNES, NASA, ESA, CNSA/NSSC

Schedule

May 2022 – Feb 2025   Total time to complete: 33 months

Schedule Milestones	**Forecast**	**Comments**
Project Approved	30 June 2022	Following Spring 22 meeting
Internal WG Review		
- First draft circulated to WG	October 2022	At Fall 22 meeting
- Second draft circulated to WG	May 2023	At Spring 23 meeting
- Second draft comments due	October 2023	Before Fall 23 Meeting
- Final WB Submitted to AD for further processing	December 2023	Two months after comments due
External Milestones		
Secretariat Document Processing	April 2024	
Agency Review	August 2024	Complete before Fall 24 meeting
RID Resolution	October 2024	At Fall 24 Meeting
Prototype Development	April 2024	Concurrent with draft development
CMC Approval	February 2025	Includes CESG Poll + CMC Poll for PUBLICATION